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DEFLUORIDATION IN INDIAN SCENARIO: PRESENT AND FUTURE PERSPECTIVE

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ABSTRACT

Fluoride is frequently depicted as a 'double-edged sword' as an insufficient intake is related to dental caries and too much ingestion leads to dental and skeletal fluorosis which has no treatment. Prevention is only through the supply of fluoride safe water by using defluoridation techniques. This review article is aimed at providing specific information on attempts made by various researchers in the field of fluoride removal from polluted waters. Various de-fluoridation techniques are currently in use viz., precipitation, ion-exchange, reverse osmosis, electro dialysis, donnan dialysis, nanofiltration, electro coagulation and adsorption etc. And among these techniques, adsorption process is economical, efficient, ease of operation and produces high-quality water. Studies on fluoride removal from waste waters using various adsorbents such as alumina/aluminium based materials, lime, clays and soils, calcium based minerals, bone, bone char, synthetic compounds and carbon based materials are reviewed. The present paper reviews the techniques available and on-going attempts for fluoride removal from polluted waters in India.

KEYWORDS: Fluorosis, de-fluoridation techniques, adsorption.

Safe and potable drinking water is essential for survival of human beings. Fluorides in drinking water may be beneficial or detrimental depending on its concentration and total amount ingested. Fluoride is beneficial when present within permissible limits of 1.0 – 1.5 mg /L while when in excess fluorides in drinking water cause dental fluorisis and/or skeletal fluorosis.[1] India is one of the 23 nations in the world where higher fluoride concentration in water is creating problems. About 62 million individuals among which 6 million are children in 17 states are affected with dental, skeletal and non-skeletal fluorosis. The extent of fluoride in ground water varies from 1.0 to 48.0 mg/L.[2] Defluoridation of drinking water in fluorosis-endemic areas is part of the National Programme for provision of safe drinking water. Fifteen out of 30 states and Union Territories of the Indian Republic are considered endemic for fluorosis and the defluoridation programme attempts to correct this situation.[3]

Defluoridation is "adjustment of level of fluoride in drinking water to the optimal level". It is better to select an appropriate de-fluoridation technique by considering the local conditions, economic status, adoptability of the method, knowledge of community, easy availability of materials and reuse of exhausted materials for treatment purpose etc. The techniques which use locally and cheaply available materials as de-fluoridation agents are preferred. Now-a-days, varieties of methods are available for fluoride removal mainly based on the mechanism such as precipitation, ion-exchange, reverse osmosis, Donnan dialysis, electro dialysis, nano filtration, membrane based methods, electro coagulation and adsorption on to various adsorbents.[4] Each approaches have their advantages and limitations and worked productively under ideal condition to remove fluoride to more noteworthy range. All the above approaches are examined briefly with their advantages and limitations.

Precipitation Methods

Precipitation methods are based on the addition of chemicals (coagulants and coagulant aids) and the subsequent precipitation of a sparingly soluble fluoride salt as insoluble fluorapatite.[5] The best example for this technique is the famous Nalgonda technique of de-fluoridation developed by National Environmental Engineering Research Institute (NEERI), Nagpur in 1961. It involves addition of Aluminium salts, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation, filtration and disinfection.

Merits

1. It can be used both at both domestic and community levels.
2. Operations are possible manually.
3. The chemicals are the same as those used in municipal/urban water supply schemes.
4. It is cost effective.
5. A variety of designs and models have already been developed by NEERI fOI use in different locations.

6. There is considerable flexibility in design considerations; therefore location specific alterations are possible.
7. Defluoridated water meets with the standards laid down by the Bureau 01 Indian Standards, that is, the fluoride content in water shall be lower than 1 ppm.[3]

Demerits

1. The Nalgonda technique is more time consuming and requires more diligence than other de-fluoridation techniques.
2. It is difficult to regulate the pH with the addition of lime, the correct dose of chemicals to be added.
3. Removes only (18-33%) of fluoride in the form of precipitates and converts (67-82%) of fluoride into soluble toxic Al3+- F complex ions.
4. A large dose of aluminium sulphate, up to 700-1,200 mg/lit, may be needed. The large dose results in a large sludge disposal problem in the case of water works treatment and sulfate ion concentration crosses the maximum permissible limit of 400 mg/lit, which causes ill-effects in human beings.
5. The residual aluminum in excess of 0.2 mg/lit in treated water causes dangerous dementia disease as well as pathophysiological, neuro-behavioral, structural and biochemical changes.
6. It also affects musculoskeletal, respiratory, cardiovascular, endocrine and reproductive systems.[6]

Nalgonda technique, disregarding introductory achievement, did not take off in light of some intrinsic issues.

Ion-exchange resins

For de-fluoridation of water various types of anion and cation exchange resins have been used. Some of the anion exchangers are Tulsion A-27, Deaceodite FF-IP, Amberlite IRA 400, Lewatit MIH-59, Polyanion (NCL), Amberlite XE-75 and cation exchangers are Carbion, Wasoresin-14, Polystyrene resin, Sulphonated saw dust carbon.

Demerits

1. A large volume of regenerate is required for the regeneration of cation and anion exchange resins.
2. The resins are complex, contamination prone and expensive and the waste produced is very large.

Membrane Filtration Process

Reverse osmosis (RO) and electro dialysis are two membrane filtration processes which can be used for the removal of fluoride. De-fluoridation studies on membrane based have been reported in Finland.[7] In reverse osmosis, the pressure is exerted on one side of the semi-permeable membrane which forces the water across the membrane leaving the pollutants behind and extremely high pure water is produced. In electro dialysis, the membranes allow the ions to pass but not the water. In electro-dialysis pollutants (ionic components) can be removed from aqueous solution through ion exchange membranes under the influence of an electric field.

Demerits

1. The membranes are sensitive to temperature, pH and arises maintenance problem because of plugging, fouling by particulate matter, concentrated with large quantity of wastes.
2. Both the processes are expensive and very complicated.
3. Removes all the ions present in water including some essential minerals for proper growth and hence remineralization is required after treatment.
4. High energy consumption and large amount of water gets wasted as brine.

Donnan dialysis

Donnan dialysis is also a separation process based on membrane filtration that utilizes counter diffusion of two or more ions through an ion-exchange membrane to achieve a separation. The process is named in honor of F. G. Donnan[8] who described the equilibrium that resulted when a semi-permeable membrane separated two solutions of electrolytes, NaA on one side and KA on the other. Donnan dialysis (DD) is highly efficient in treating fluoride contaminated water and used for the treatment of low-concentration waters.

Demerits

1. Reduced efficiency in high-saline waters.
2. Expensive technique.

Nano filtration

Nano filtration is a process which takes in the upper end (in separation size terms) of reverse osmosis, and the lower end of ultra filtration. Permeability of Nano filtration membranes is higher than those of RO. Nano filtration membranes have high retention of charged particles. It requires less pressure and capital than RO and it is widely applicable specially for drinking and waste water treatment and is used in de-fluoridation studies.[9,10]

Demerits

1. The process is expensive and complicated.

Electro Coagulation

The electro coagulation is the process of utilizing electricity and sacrificed anodes to form active coagulant which is used to remove pollutant by precipitation and flotation. The conductive metal plates are commonly known as sacrificial electrodes. Electro coagulation process requires less space and does not require chemical storage, dilution and pH adjustment. It is proven to be effective in water treatment such as drinking water supply for small or medium sized community.[11]

Demerits

1. The process is expensive and complicated.

Adsorption Process

The adsorption process of fluoride on to the surface of adsorbent may be either physical or chemical depending on the nature of forces involved. To select an adsorbent for de-fluoridation process, we must consider the adsorption capacity of an adsorbent in dilute solutions, dosage, pH, temperature, and time required for fluoride removal, loading capacity in presence of interfering ions and finally the overall cost for de-fluoridation. A large number of effective, low-cost adsorbents such as activated alumina, amorphous alumina, calcite, rare earth oxides, bleaching earth, fly ash, limestone, clay minerals, bone char, heat-activated bauxite, natural soil, red mud, Magnesium incorporated bentonite clay, Titanium rich bauxite, Brick powder, Hydrated cement, Pumice, Acid activated kaolinite clay, iron(III)-aluminum (III) mixed oxide etc.

From all the above discussions, it has been observed that so many techniques are available for removal of excess fluoride from the drinking water but every technique has both advantages and disadvantages. So, a single method cannot be accepted properly for all areas. Hence, according to the conditions like area, concentration, availability of resources etc. any one method can be selected for removal of excess fluoride from the drinking water. But out of all the above said techniques, for de-fluoridation of water, adsorption techniques have more advantages because of their greater accessibility; do not require complicated hardware, inexpensive and capable of removing fluoride from water up to maximum extent.

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